

Translating Fengshui into algorithmic design

A digital tool to examine the impact of Fengshui on Siheyuan's layout

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In continuation of our previous work on the design principles of traditional Beijing Siheyuan courtyard housing and their implementation into computational algorithms, this paper investigates the impact of the Fengshui theory on its layout. In particular, we will present the development of a Grasshopper algorithm able to examine Siheyuan houses' fortune status according to their layout. We have verified the algorithm by using Siheyuan precedence from the ancient Beijing map and measuring surveys on extant buildings. Our findings highlight that most Siheyuan houses were designed to be auspicious even though other forces were working against

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INTRODUCTION

Courtyard housing was the most common dwelling type in ancient China. The Siheyuan, traditional Chinese courtyard housing type from Beijing, is a typical representative of traditional Chinese vernacular architecture. A typical Siheyuan consists of axially aligned courtyards symmetrically surrounded by individual buildings connected by orthogonally located corridors, walls, and gates, as illustrated in Figure 1.

When Beijing was rebuilt between the Yuan and Qing dynasty, Siheyuan became one of the most potent symbols of imperial rule. As the basic cell of ancient Beijing's urban texture, it embodied the rules of feudal society in its architectural form. Many studies such as by Ma (1999), Zhao (2013), and Lu and Wang (2013), have paid attention to its archetypal form in traditional feudal society.

After Liang and Chen's urban planning proposal to preserve historical Beijing city was rejected by the Beijing government in 1950, many Siheyuan houses were damaged or destroyed up to the present day. One of the consequences of this destruction is that current architects lack knowledge of its principles, thus their Siheyuan design projects are considered as fake. In support of the preservation and popularization of Siheyuan design knowledge, many studies re-introduced its design principles using historical records. For example, Ma (1999), and Lu and Wang (2013) comprehensively introduced forms of architectural components of traditional Siheyuan based on extant buildings and historical materials. Zhao (2013) studied tectonic methods of Siheyuan's architectural components by the understanding of ancient construction rules and interviews with successors of ancient craftsmen.

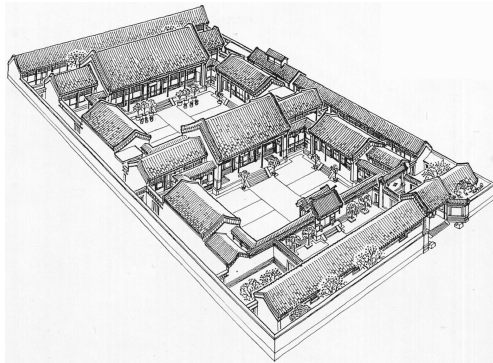


Figure 1
Beijing Siheyuan,
after Ma, 1999.

On the other hand, three computational approaches created by western scholars, shape grammar (Stiny, 2006), space syntax (Hillier and Hanson, 1984) and pattern language (Alexander et al., 1977) were employed in Chinese courtyard housing studies to explore its design logic. Chiou and Krishnamurti (1995a) developed the grammar of vernacular dwellings in Taiwan, a branch of Chinese courtyard housing, which enhanced the understanding of its design. Huang et al. (2018) analysed the spatial configuration of an ideal archetypal model using DepthX Map and advised to inherit Siheyuan's cultural connotations in contemporary housing design. Liu (2019) studied the composition of walls and rooms on Siheyuan examples recorded on the historical map *Jingcheng Qianlong Quantu* (1750) by categorizing types of courtyards. Their classifications of patterns of courtyards and rooms revealed the design constraints underlying practice.

In ancient Chinese philosophy, the cosmic aspect of nature is the essence of everything. Therefore, ancient Chinese knowledge about it was applied to many subjects by analogy. Fengshui (cloud and water) is geomancy based on this analogy to guide adapting cities and buildings to achieve harmony with nature. There are two branches of Fengshui theory: *Xing Shi* (observing context) and *Li Qi* (regulating vital energy). The *Xing Shi* helps geomancers to select an auspicious site and the *Li Qi* based on the concept of “cosmic resonance” helps

craftsmen and householders predict and select auspicious orientations, qualitative space, and dimensions of rooms in the design process.

Even though there are a great number of studies on Siheyuan design, the important cultural factor, Fengshui, has rarely been explored for its influence on Siheyuan's architectural form. In the context of Taiwanese vernacular dwellings, Chiou and Krishnamurti (1995b) investigated the method from *Li Qi* to determine the fortunate dimension of a building using the ancient measuring ruler *Lu Ban Chi* and interpreted it in an algorithmic format. Later, they (1997) also introduced applications of *Li Qi* in finding fortunate orientations of a site and auspicious dates to start building construction and implemented it in computers. Meanwhile, Wang et al. (2019) created an interactive tool to parametrically design Siheyuan following Fengshui, in which assessment rules of the fortune of Siheyuan site context from *Xing Shi* were embedded. Although this research made passing reference to the principles of Fengshui on architectural design, the implementation of Fengshui in the Siheyuan's form in practice has rarely been investigated. This study aims to explore how principles from Fengshui constrain Siheyuan design as well as investigate how Fengshui harmonizes with other cultural forces to influence Siheyuan's form in practice, through the development of an algorithmic tool. In particular, our main aim addresses the three research questions:

1. How do Fengshui principles influence Siheyuan design?
2. How can these principles be implemented into algorithmic design and be applied as an interactive tool for examining the fortune of a Siheyuan house?
3. Were these principles being applied in traditional Siheyuan design practice?

To answer these questions, we have first studied the Fengshui theory based on historical material and interviews with Fengshui geomancers to clarify the original principles relating to Siheyuan design. We

Figure 2
The ideal
environmental
context from Xing
Shi.

have then analyzed the mathematical logic underlying its principles to produce an algorithm using the *Grasshopper* visual scripting platform. Finally, we have employed this algorithm as a tool to examine the fortune of historical Siheyuan cases, whose corpus has derived from measuring surveys of extant Siheyuan examples and documented historical examples.

MATERIALS AND METHODS

Source of rules

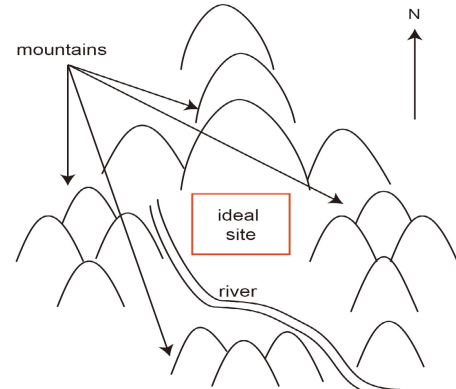
As stated above, *Xing Shi* is used to finding proper sites for building construction while *Li Qi* is to find fortunate orientation, size ratio, and the dimension of buildings. *Li Qi* dominantly shapes the form of Siheyuan. Principles in Fengshui constraining orientation, size ratio, and dimensions of buildings were selected to study, which were originally recorded in historical books such as *Dili Huitu Wu Jue* (*Five Tips For Geographic Mapping*, Zhao, 1785/2011a), *Bai Zhai Ming Jing* (*Eight Mansions Bright Mirror*, Gu, 1790/2010), *Yang Zhai San Yao* (*Three Essences of Positive Houses*, Zhao, 1786/2011b).

Methods

Many previous architectural Fengshui studies, as noted, centred on its metaphysical and anthropological aspects but neglected to examine its influence on its building form. However, Chiou and Krishnamurti (1997) illustrated the potential to solve this problem by using an algorithm to interpret the application method of Fengshui. Taking this idea further we uncover Fengshui's influence with a digital interactive tool developed in *Rhino/Grasshopper*. Since Fengshui influences buildings in orientation, size ratio, and dimension, we were able to test our algorithm by entering data of historical Siheyuan examples into the tool to generate results shaped by Fengshui principles and then compare them with corresponding historical ones.

ANALYSIS OF FENGSHUI PRINCIPLES

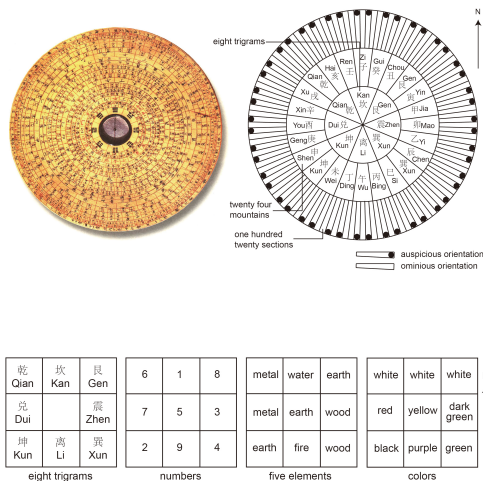
Fengshui geomancers supposed a kind of mysterious energy called *Qi* flows in the air in the form of invisible gas. This gas brings good fortune to people. *Li Qi* is the method to steer this energy. In the case of Siheyuan, the proper size ratios and function of rooms can store this energy in the housing space.



Room Orientation

As shown in Figure 2, *Xing Shi* gives an ideal environmental context in Fengshui for a building's or a city's site. The site should be surrounded by hills and mountains (the highest and largest mountains at its north side), located on the smooth ground with its main elevation facing south and a river crossing its front area. However, as Beijing's urban area had been subdivided into an urban grid system, it is almost impossible to find this ideal context. Referring to the original considerations of Fengshui and regarding the urban planning of ancient Beijing, we simplified the principles into two main constraints: 'being within the auspicious degree ranges of orientation' or 'facing an adjacent street or alley'. The simplest way to find the auspicious degree is to use a Fengshui compass, which averagely divides a 2D plane into 24 sections (called '24 mountains') by 15 degrees and additionally divides each section into 5 subsections by 3 degrees, as shown in Figure 3. Degrees located within each second and fourth subsection are

defined as auspicious orientation. The first constraint requires the elevation of the primary room of each courtyard in Siheyuan orientated within the range of auspicious degrees. The second requires it facing an adjacent street or alley, but there are two exceptions. If the adjacent street or alley exists on the north, primary rooms face the opposite direction. If adjacent streets or alleys exist on multiple sides, there is a priority sequence of determination of primary rooms orientation: south> east> west> north.



Room Size Ratios

Size ratios of rooms in a courtyard are various. In Fengshui, there are many methods to identify room size ratios., such as *Da You Nian* (big tour calendar), *Chuan Gong Jiu Xing* (crossing courtyard nine stars), *Fen Fang Jie Lu* (dividing rooms and intercepting paths), whose logics are the same but the determination of parameters or the applicable types of Siheyuan vary. Siheyuan is classified into three types: one-courtyard Siheyuan, Siheyuan with multiple courtyards aligned in the depth direction, Siheyuan with multiple courtyards aligned orthogonally. Here we propose the method of one courtyard Siheyuan and then supplement the differences be-

tween it and the method of the other two Siheyuan types.

For one-courtyard Siheyuan:

1. Divide the courtyard of the Siheyuan into nine areas with a three-by-three grid, and then allocate the eight trigrams (*Bagua*) to the eight boundary areas (the central area is left as empty) according to its orientation. The allocation of each trigram corresponding to the eight boundary areas are: east-*zhen*, southeast-*xun*, south-*li*, southwest-*kun*, west-*dui*, northwest-*qian*, north-*kan*, northeast-*gen*. The principle to allocate the eight trigrams to the eight boundary areas comes from the identification of attribute of each area recorded in *Luo Shu* (*Decusation Rivers Book*). The attribute of an area includes one of eight trigrams, one of the five elements (*Wuxing*), a number between one and nine, and one of seven colours, which depends on the area's location, as shown in Figure 4.
2. Identify the area of fortune origin. The area of fortune origin is where the centre point of the keyspace locates. Either the entry gate or the primary room could be the keyspace. It is important to state to the selection of the type of the keyspace (the entry gate or the primary room).
3. Assign the 'nine stars (*Jiu Xing*)' to eight trigrams according to the location of the area of fortune origin. In Fengshui, the seven stars of the Great Bear constellation and two nearby stars, called 'nine stars', were analogized with meanings of fortune. Each of the nine stars is assigned with fortune, as shown in Table 1. Each of the eight boundary areas is associated with one of the nine stars. Once the area of fortune origin is identified, each area's associating star(s) is(are) determined. Geomancers created a pithy formula to represent the eight results corresponding to the eight each of the eight areas as being the area of fortune origin. The eight results are shown in Figure 5.
4. Calculate the fortune of each area by the principles 'five elements produce and destroy'. The

Figure 3
A Fengshui
compass and
fortunate
orientation.

Figure 4
Area attribute.

Figure 5
Eight results of
assigning the nine
stars to eight
trigrams.

Table 1
Correspondence
between the nine
stars, five elements,
and their fortune.

Figure 6
Five elements
produce and
destroy principles

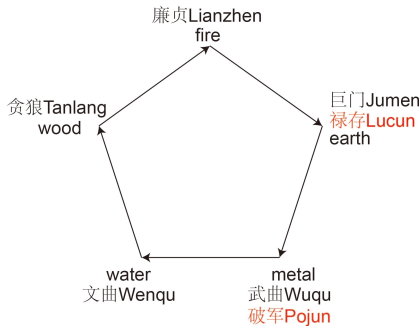
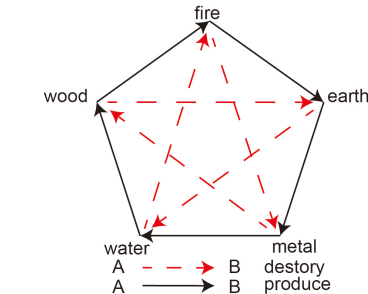
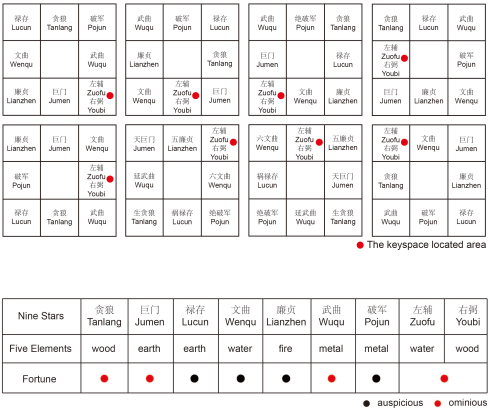
Figure 7
Order of Na-tone
five elements. (the
stars Pojun and
Lucun only exist in
the mid area of the
first courtyard.)

concept of ‘five elements’ comes from *Luo Shu*, in which each of the eight trigrams attributes an element within the five: metal, wood, water, fire, and earth. The correspondence between trigrams and elements are shown in Figure 4. Each star of the nine stars is assigned with fortune and also one of the five elements as an attribute, shown in Table 1. Between every two elements, there is a ‘destructive’ or ‘productive’ relation as shown in Figure 6. The way for identifying the fortune of an area is using the element of the star assigned in this area to compute with the element of the trigram of the area of fortune origin. For each area assigned with an auspicious star, a) if the element of the star is in ‘destroy’ relation with the element of the trigram, the area is lesser auspicious, and b) if the element of the star is in ‘produce’ relation with the element of the trigram or they are the same, the area is greater auspicious. For each area assigned with an ominous star, a) if the element of the star is in ‘destructive’ relation with the element of the trigram, the area is lesser ominous, and b) if the element of the star is in ‘productive’ relation with the element of the trigram or they are the same, the area is greater ominous. For the *Zuofu* star and *Youbi* star, the area they belong to is always least auspicious.

For Siheyuan with multiple courtyards aligned in the depth direction, there are four differences:

- Step 1 is applied to each courtyard of the Siheyuan separately,
- Only the entry gate could be the keyspace.
- The trigram and the star of each of eight boundary areas in the first courtyard are identified in the way the same as it is for one-courtyard Siheyuan, and this pattern is applied to all courtyards except the mid back area.
- Assign the corresponding star of the mid-front area of the first courtyard and then assign the star of the mid-back area of each courtyard sequentially according to the order of production

of the ‘Na-tone five elements’, as illustrated in Figure 7.



For Siheyuan types with multiple courtyards aligned orthogonally: each courtyard could be seen as an individual Siheyuan to compute.

The fortune of area forces size ratios and functions of rooms constructed in each area. Normally, rooms in auspicious areas are large while in ominous areas are small. Two examples of the process for a one-courtyard Siheyuan and a Siheyuan with five courtyards aligned in the depth direction are illustrated in Figure 8.

Room Dimensions

The ‘Pressing White Ruler Method’ from Fengshui identifies the fortune of dimension, which filters the ranges of dimensions by Lu Ban rulers. In this method, there are two principles, the *Chi Bai* (feet white) and the *Cun Bai* (inch white) constraining the dimensions in parallel. Since only the *Chi Bai* are applied to dwellings normally and most Siheyuans are dwellings, we analysed the *Chi Bai* principle, which consists of five steps:

1. Identify the orientation of the room's door within the 24 mountains of a compass (figure 3) and then find its opposite section on the compass.
2. Use the ‘earth mother selecting first’ (*Di Mu Na Jia*) principle to identify the trigram of the opposite section in the eight trigrams. The correspondence between the twenty-four mountains and the eight trigrams are shown in table 2.
3. Find the corresponding colour and number of the trigram in Luo Shu and then use it as the first range on a Lu Ban ruler. The correspondence between trigrams and numbers is shown in table 3. This correspondence has two variations: the heaven trigram and the earth trigram. The heaven trigram is to determine fortune dimensions in the vertical direction- the height of the building, and the earth trigram is to determine fortune dimensions in horizontal direction- width and depth of the building.
4. Identify the sequence of numbers. Based on the first number to assign each range's number re-

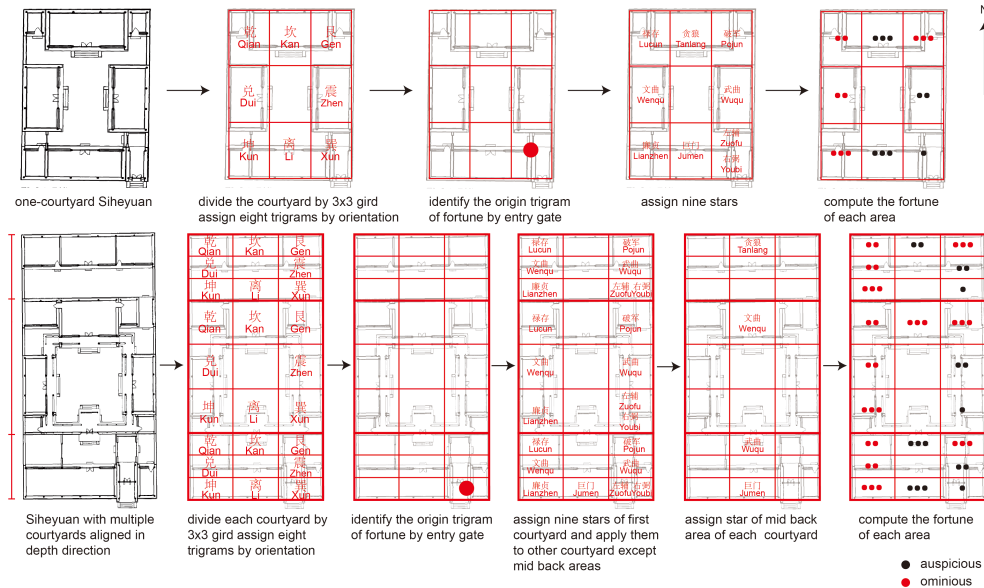


Figure 8
Two examples of the process of computing room size ratios of areas.

peatedly on the Lu Ban ruler in numerical order from Luo Shu, as illustrated in Figure 4. In the assignment, the heaven trigram excludes number 1 and the earth trigram excludes number 9. 1 range= 3.2 centimetres. Each number indicates its fortune.

- Use each auspicious colour's corresponding element in the five elements to compute with the element identified in 24 mountains by the building's orientation (Figure 3) according to the principles "five elements produce and destroy". If the two elements are the same or in 'productive' relation, the colour's corresponding range is identified as auspicious, otherwise, as ominous.

Table 2
The
correspondence
first number of each
trigram in the eight
trigrams.

number	1	2	3	4	5	6	7	8	9
the heaven trigram		坎Kan	坤Kun	乾Qian	巽Xun	艮Gen	震Zhen	离Li	兑Dui
the earth trigram	乾Qian	离Li	震Zhen	兑Dui	坎Kan	坤Kun	巽Xun	艮Gen	

Table 3
The
correspondence
between the
twenty-four
mountains and the
eight trigrams in
the "earth mother
selecting first"
method.

eight trigrams	乾Qian	坎Kan	艮Gen	兑Dui	震Zhen	巽Xun	离Li	坤Kun
twenty four mountains	乾Qian 甲Jia	癸Gui	丙Bing 申Shen 子Zi 辰Chen 艮Gen	丁Ding 巳Si 酉You 丑Chou	庚Geng 亥Hai 卯Mao 未Wei	辛Xin 巽Xun	壬Ren 寅Yin 午Wu 戌Xu	乙Yi 坤Kun

DEVELOPING THE ALGORITHM

Based on the analysis explained above, we identified four key input parameters for *Grasshopper* to determine Siheyuan houses' fortune. They are: for the orientation of the Siheyuan house, a) the location of the adjacent street or alley, for the rooms size ratios in a courtyard, b) the selection of the type of the keyspace and c) the location of the keyspace, and for the dimension of each room, d) the orientation of the room. Accordingly, we produced an interactive *Grasshopper* script for the implementation of the algorithm to identify the fortune of the house's orientation, room size ratios, and room dimensions. The workflow is illustrated in Figure 9.

To implement the algorithm in *Grasshopper*, the plan of a Siheyuan and site context is imported. In

our *Grasshopper* script, streets or alleys of the Siheyuan are identified by being collected by *Curve* components. The surrounding area of a Siheyuan site is identified and divided into four parts (north, south, east, and west) and collected by *Curve* components to find adjacent streets or alleys. The selection of the type of the keyspace is indicated by a 'silder' component, whose values are to be inputted. The plan of the keyspace is identified by a 'curve' component to find their central positions and then identify their locations within the 3x3 grid. The orientation of each room is identified by a Vector 2Pt component, whose orientation is from the central point of the room to the central point of the line indicating as the room's front elevation on the plan.

VERIFICATION

To verify whether Fengshui was used in Siheyuan design to obtain auspicious patterns, we used our tool to identify the fortune of Siheyuan examples by deriving the value of parameters from the precedents and then examining whether they are auspicious or not.

The Qianlong capital map (1750) presents all the buildings of Beijing at a scale of 1: 650, including thousands of Siheyuan houses. Duan (2016) organized measured surveys on existing Siheyuan examples. We selected two examples(left two in Figure 10) from the map and another two from Duan's surveys(right two in Figure 10), which are the most common types according to Ma (1999), Zhao (2013), Lu and Wang (2013), and Wang and Song (2012). However, the map and the measuring surveys cannot be used for verifying rooms' dimensions as well as we would like. Alternatively, examples of individual buildings recorded in *Gongcheng Zuofa Zeli* were used to replace rooms in the selected examples since they are described with detailed dimensions. The individual buildings in this manual have been drawn by Liang (2006), who translated texts in the manual into architectural drawings with detailed dimensions noted. We assumed the dimensions of the primary rooms of our selected examples are the same as in

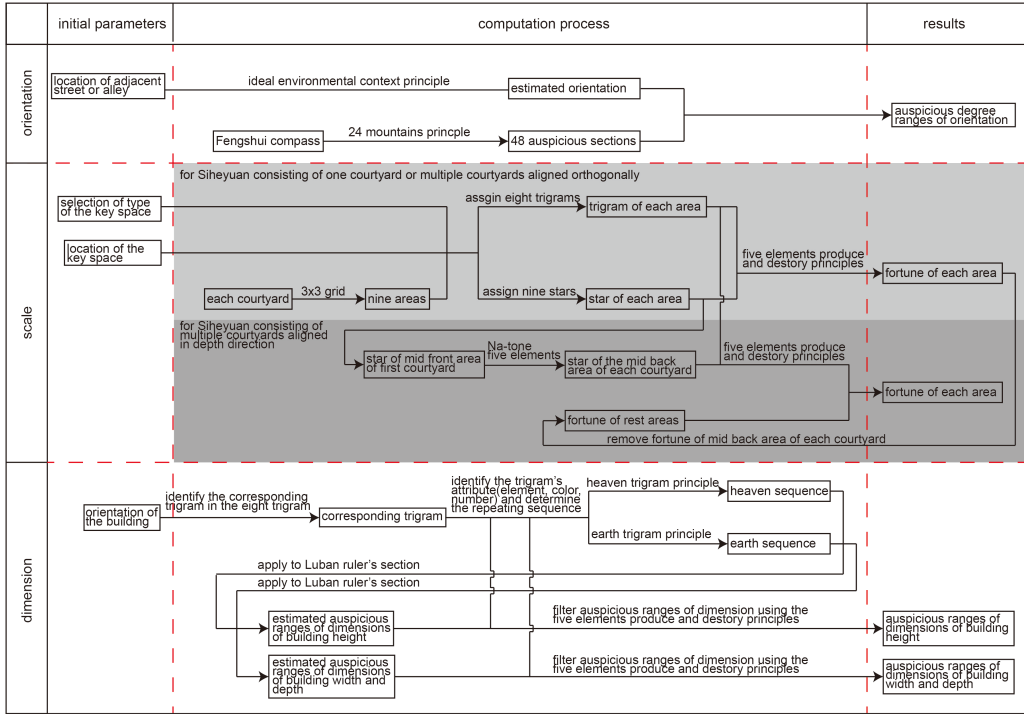


Figure 9
The workflow of
Fengshui principles
translated into a
Grasshopper script

Liang's drawings. To be consistent with the Siheyuan rooms, a building given by Liang (2006) was modified by reducing the number of bays in the front view from five to three (in Figure 11) and then used as a primary room for verification. Figure 10 shows how our models assessed the fortune of our examples.

DISCUSSION AND CONCLUSION

The results of the verification of four selected examples confirmed the Fengshui principles since they are mostly auspicious. We noted that other influence, more important than Fengshui, are also at work. For this reason, even the most common types, which are the closest to Siheyuan's ideal prototype, did not completely follow Fengshui to create auspicious patterns. For example, Confucianism and Taoism con-

strain rooms in a courtyard to be axial, and feudalism and clan constrain the size ratios of rooms in a courtyard in the sequence: primary room> east secondary room= west secondary> primary east wing room= primary west wing room> secondary east wing room= secondary west room. This constraint of room size ratio is more dominant than the one from Fengshui, so it can be easily observed that most Siheyuan houses follow this pattern. Meanwhile, to make Siheyuan conform to Fengshui, craftsmen would slightly change the room sizes to ensure size ratios of rooms are in auspicious patterns, which is hard to prove without conducting a measuring survey. This is the reason why, in many Siheyuan examples, the east wing room is slightly larger than the west wing room within a courtyard. Another exam-

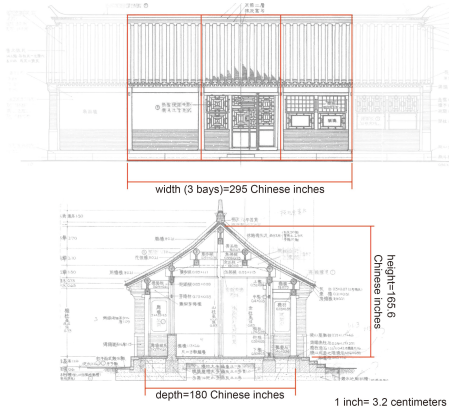
Figure 10
Verification of four
examples.



ple is the simplification of the *Cun Bai* method. The rules in *Gongcheng Zuofa Zeli* and consideration of material consumption constrained the available dimensions of a room in limited ranges. The constraint deriving from Fengshui dictates additionally limited ranges for room dimensions, but the ranges of each room may vary because it is a variable parameter for

each room of a *Siheyuan*. This variability of room dimensions results in difficulty in building construction. However, in many cases, the limited ranges of room dimensions constrained by Fengshui are unified by simplification of the *Cun Bai* method. As a result of the simplification, instead of using the orientation of a room as the parameter to conduct the com-

plex calculation, the *Lu Ban* ruler, which consists of 9 units marked by their fortune type, is directly used to find auspicious dimensions of a building in practice. We infer this simplification is to solve the difficulty in building construction since it unified limited ranges of room dimensions constrained by Fengshui.



There are two limitations to our study. First, for the verification of room dimensions, we have used ideal examples of buildings with constant values of dimensions according to *Gongcheng Zuofa Zeli*, but an individual building's dimensions could vary in practice, which may lead to errors of verification of room dimensions. Second, in this study, we only verified the most common Siheyuan types rather than all variations, whose Fengshui assessment results might possibly be different. Further research is needed to verify if Fengshui applies to these variants.

REFERENCES

Alexander, C, Ishikawa, S and Silverstein, M 1977, *A pattern language: Towns, buildings, construction*, Oxford University Press, New York

Anon, Anon 1734, *Gongcheng Zuofa Zeli (Structural Regulations)*, Qing Engineering Department, Beijing

Choiu, S and Krishnamurti, R 1995a, 'The grammar of Taiwanese traditional vernacular dwellings', *Environment and Planning B: Planning and Design*, 2(6), pp. 689-720

Choiu, S and Krishnamurti, R 1995b, 'The fortunate

dimensions of Taiwanese traditional architecture', *Environment and Planning B: Planning and Design*, 22(5), p. 547 – 562

Choiu, S and Krishnamurti, R 1997, 'Unraveling fēngshu', *Environment and Planning B: Planning and Design*, 24(4), pp. 549-592

Duan, B (eds) 2016, *Beijing Siheyuan Zhi(Beijing Siheyuan Chronicle)*, Beijing Press, Beijing

Gu, W 2010, *Eight Mansions Bright Mirror.*, World Knowledge Press., Beijing. First released in 1790

Hillier, B and Hanson, J 1984, *The Social Logic of Space.*, Cambridge University Press, Cambridge

Huang, B, Chiou, S and Li, W 2019, 'Study on courtyard residence and cultural sustainability: Reading Chinese traditional Siheyuan through Space Syntax', *Sustainability*, 11(6), p. 1582

Liang, S 2006, *Diagrams of Qing Gongbu Gongcheng Zuofa Zeli (Building Regulation by Qing Work Ministry)*, Tsinghua University Press, Beijing

Liu, D 2019, 'An Intensive Analysis of the Typical Urban Micro-Fabrics of Beijing in Middle Qing Dynasty: Taking the Area in Northeast of the East Four Archways in Qianlong Jingcheng Quangu for Example', *History of Architecture*, 2(1), pp. 130-152

Lu, X and Wang, Q 2013, *Beijing Siheyuan Renju Huanjing (Beijing Siheyuan Human Settlements Environment)*, China building industry press., Beijing

Ma, B 1999, *Beijing Siheyuan Jianzhu (Buildings of Siheyuan in Beijing)*, Tianjin University Press, Tianjin

Stiny, G 2006, *Shape: talking about seeing and doing*, The MIT Press, Cambridge

Wang, Y, Agkathidis, A and Crompton, A 2019 'Parametric Beijing Siheyuan: An algorithmic approach for parametric generation of Siheyuan housing variants based on its traditional design principles', *Proceedings of the 37st eCAADe/ XXIII SIGraDi*

Zhao, J 2011a, *Dili Huitu Wu Jue (Five Tips For Geographic Mapping)*, Hualing Press., Beijing. First released in 1785

Zhao, J 2011b, *Yang Zhai San Yao (Three Essence of Positive Houses)*, Hualing Press., Beijing. First released in 1786

Zhao, Y 2013, *Beijing siheyuan traditional constructional technique.*, Anhui Science and Technology Press, Hefei

Figure 11
The dimensions of a building example applied in Siheyuan as primary rooms. After Liang, 2006.